# A GRAPHICAL DISPLAY FOR CUEING HELICOPTER MAIN ROTOR AERODYNAMIC BRAKING

## BACKGROUND OF THE INVENTION

[0001] The present invention relates to a display for assisting the pilot of a helicopter in aerodynamically braking the main rotor of the helicopter during a helicopter shutdown procedure within a specified shutdown time.

[0002] Many current production helicopters feature a mechanical rotor brake for slowing the main rotor to a stopped condition. The brake is manually controlled by the pilot in the cockpit. A mechanical rotor brake adds weight and complexity and requires periodic maintenance. Also, the presence of the mechanical brake in the main rotor drive system and the associated linkages to a cockpit lever arm uses valuable space which must be designed into the airframe. The weight and space penalty for a mechanical rotor brake add significant cost to the aircraft.

[0003] A more advanced system for cueing helicopter main rotor aerodynamic braking is needed.

## SUMMARY OF THE INVENTION

[0004] Accordingly, it is an object of the present invention to provide a display for cueing helicopter main rotor aerodynamic braking.

[0005] It is a further object of the present invention to provide a display as above which cues a pilot with the proper direction in which to orient a rotor disk without exceeding main rotor flapping structural limitations.

[0006] The foregoing objects are attained by the display system of the present invention.

[0007] In accordance with a first aspect of the present invention, a display is provided for cueing helicopter main rotor aerodynamic braking. The display broadly comprises first indicia representing wind direction, second indicia representing main rotor roll control, third indicia representing main rotor pitch control, and fourth indicia representing a margin from main rotor flapping limit.

[0008] In accordance with a second aspect of the present invention, a system for assisting a pilot in aerodynamically braking a main rotor during an aircraft shutdown procedure is provided. The system broadly comprises a plurality of sensors for sensing a plurality of aircraft parameters, a processor for processing the sensed aircraft parameters and means for cueing the pilot with the proper direction in which to orient a rotor disk without exceeding

main rotor flapping shaft structural limitations.

**[0009]** In accordance with a third aspect of the present invention, a method for assisting a pilot in aerodynamically braking a main rotor during an aircraft shutdown procedure is provided. The method broadly comprises the steps of providing a display having crossbars representative of longitudinal and lateral cyclic control position and a symbol representative of wind direction vector, and overlaying the crossbars with the wind direction vector so as to orient a rotor disk such that a freestream air inflow angle is down through the rotor.

**[0010]** Other details of the graphical display for cueing helicopter main rotor aerodynamic braking of the present invention, as well as other objects and advantages attendant thereto, are set forth in the following detailed description and the accompanying drawings wherein like reference numerals depict like elements.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0011]** FIG. 1 is a representation of a graphical display in accordance with the present invention to be provided to a pilot of a helicopter; and

**[0012]** FIG. 2 is a schematic representation of a system for generating the graphical display of FIG. 1.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

[0013] Referring now to the drawings, FIG. 1 illustrates a graphical display 10 which is designed to assist the pilot in aerodynamically braking the main rotor of a helicopter during an aircraft shutdown procedure within shutdown time specifications. The selectable display 10, which may be generated on a multi-function cockpit panel 11, may be used on aircraft not equipped with a mechanical rotor brake.

[0014] The graphical display 10 shows a pilot wind direction data from a low airspeed sensing system such as a rotating air data system. The wind direction data is depicted by vector symbol 12. The symbol 12 rotates around the center 14 of a circle according to the wind direction at a fixed radius from the center 14 of the circle.

[0015] The graphical display 10 further includes an inner circle 18 and an outer circle 20. The inner circle 18 represents a 10% margin from the main rotor flapping limit. The outer circle 20 represents the true rotor flapping limit based on the shaft bending Do-Not-Exceed (DNE) value. A pitch bar 22, a roll bar 24, and a collective pointer 26 are depicted on the display 10 to indicate the current longitudinal, lateral cyclic and collective pitch control position. As can be seen from FIG. 1, the pitch bar 22 intersects the roll bar 24. The display 10 also includes a fixed pointer 28 which depicts the ideal collective control position (nominally full down). The vector sum of the pitch and roll control (blade pitch) parameters, depicted by the intersection of the pitch and roll bars 22 and 24, corresponds to a given magnitude of flapping. A digital indicator 30 at the top of the display 10 cues the current rotor speed.

[0016] A pilot uses the display 10 by adjusting the longitudinal and lateral cyclic control position so that the pitch and roll crossbars 22 and 24 are overlayed with the wind direction vector 12. This configuration orients the rotor disk such that the freestream air inflow angle is down through the rotor. Once the rotor is no longer windmilling, friction will overcome the induced torque and the rotor will slow down to a stop. The 10% margin caution zone defined by the inner circle 18 allows sufficient cueing so that the rotor can be stopped without incurring any fatigue damage.

[0017] As shown in FIG. 2, the graphical display 10 is preferably generated from one or more flight computers 40 which receive and process aircraft data from sensors 42 and a multi-function graphics generator 44. The flight computer(s) 40 may comprise any suitable processor(s) known in the art, which processor(s) may be programmed in any suitable programming language to process the data received from the sensors 42 and output information to the generator 44. The information output to the generator 44 preferably

includes information about the ideal collective position, the 10% margin from the main rotor flapping limit and the true rotor flapping limit. The output information also includes information about the wind direction, roll control, pitch control, collective control, and current rotor speed. The generator 44 may comprise any suitable graphics generator known in the art for generating the display indicia described above.

**[0018]** The sensors 42 may comprise any suitable sensors known in the art for sensing wind direction, main rotor pitch control, main rotor roll control, current rotor speed, and collective pitch control position.

**[0019]** The graphical display 10 may be output onto a multi-function cockpit display system when selected by the pilot during ground operations. The pilot uses the cockpit control devices, i.e. the cyclic controller for main rotor pitch and roll control, and the collective controller for main rotor thrust control, in accordance with the cues presented by the graphical display 10.

**[0020]** The success of the braking technique cued by the display 10 has been demonstrated in simulation. A typical situation has been analyzed to illustrate the general approach to the shipboard operation. This case is a 45 knot wind with a minus 10 degree inflow angle relative to the rotor shaft (blowing up through the rotor). Several different control positions were input and the resulting stop times and rotor flapping were analyzed, as shown in Table I. In the first case, using no control activity, the rotor failed to stop in the 2.5 minute specified limit. In other cases, rotor stoppage was achieved using combinations of cyclic and collective control applied at the given times.

TABLE I

| **CASE** | **Time to 20% NR(sec)** | **Time to 0% NR(sec)** | **Max Coning** | **Max Flapping** |
|---|---|---|---|---|
| Centered Controls | 62 | >150 | 1.0 | 1.4 |
| No Collective<br>6 deg Cyclic @ 40 sec | 59 | 138 | -.8 | -2.5 |
| 8 deg Collective<br>6 deg Cyclic @ 40 sec | 70 | 149 | -.8 | 2.3 |
| No Collective<br>6 deg Cyclic @ 0 sec | 48 | 127 | -.9 | -6.4 |

**[0021]** Based on these cases, the following conclusions can be made. In case 1, it can be seen that if no pitch inputs are applied, the modeled inflow windmills the rotor, and since the

induced torque is higher than the friction, the rotor will not stop. In case 2, it can be seen that with a modest input of cyclic control, the rotor will stop within the specification value of 2.5 minutes. In case 3, it can be seen that adding collective is not necessarily desirable since it did not reduce either the flapping or the stop time. Case 4 modeled a pilot error by inputting the cyclic too soon. It shows that when the cyclic is properly applied the flapping is only 2.5 degrees (no damage) and when it is done incorrectly, the resulting flapping (6.4 degrees) is damaging but substantially below the maximum maneuver condition. Thus, the rotor can be slowed without incurring any fatigue damage and will incur damage at a tolerable rate if shutdown improperly.

**[0022]** The utilization of a graphical display 10 in a cockpit for producing a controlled rotor shutdown results in substantial cost savings due to the elimination of a mechanical rotor brake. The display 10 uses input data that is typically available from modern rotorcraft sensor packages.

**[0023]** While the present invention has been described in the context of a display in a cockpit of an aircraft, it could also be used in training simulators to train pilots. For example, the graphical display of the present invention may be displayed on the display screen connected to a computer, such as a personal computer or a laptop, having one or more controls acting as a cyclic controller and a collective controller.

**[0024]** It is apparent that there has been provided in accordance with the present invention a graphical display for cueing helicopter main rotor aerodynamic braking which fully satisfies the objects, means, and advantages set forth hereinbefore. While the present invention has been described in the context of specific embodiments thereof, other alternatives, modifications, and variations will become apparent to those skilled in the art having read the foregoing description. Accordingly, it is intended to embrace those alternatives, modifications, and variations which fall within the broad scope of the appended claims.